Lunar Advanced Volatile Analysis Integration and Testing

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Key NASA Initiative:
In-Situ Resource Utilization (ISRU)

Objective

- **Move from Earth-reliant missions (resources brought or resupplied from Earth) to missions that use planetary resources such as lunar regolith or Martian atmosphere to make breathable air, water, propellants, fuels, and other supplies**

NASA simulation of International Space Station orbiting Mars, and lander, habitat, and exploration modules on Mars

In-Situ Resource Utilization

Why Mine Planetary Resources?

The Martian, 20th Century Fox, 2015

Why Mine Planetary Resources?

- Facilitate deep space exploration
- Exploit resources at planetary site (H_2, O_2 and other volatiles)
- Enable human explorers to create life support and mission-critical supplies
- Reduce mission dependence on Earth and its resupply chain
- Reduce risk and cost
- Open scientific and technological vistas

Searching for a buried sample tube at the Johnson Space Center to simulate extraterrestrial mining

Drilling into regolith simulant

Resource Prospector (RP) Mission

- **Part of ISRU**
- **First mining expedition on another world**
- **Expected to launch to moon in 2020**
- **RP Includes:**
  - **Rover hosting Regolith & Environment Science and Oxygen & Lunar Volatile Extraction (RESOLVE) payload**
  - **Lunar Advanced Volatile Analysis (LAVA) subsystem with a Gas Chromatograph-Mass Spectrometer (GC-MS).**

RESOLVE payload integrated rover during joint Kennedy – Johnson-Ames Space Centers Testing

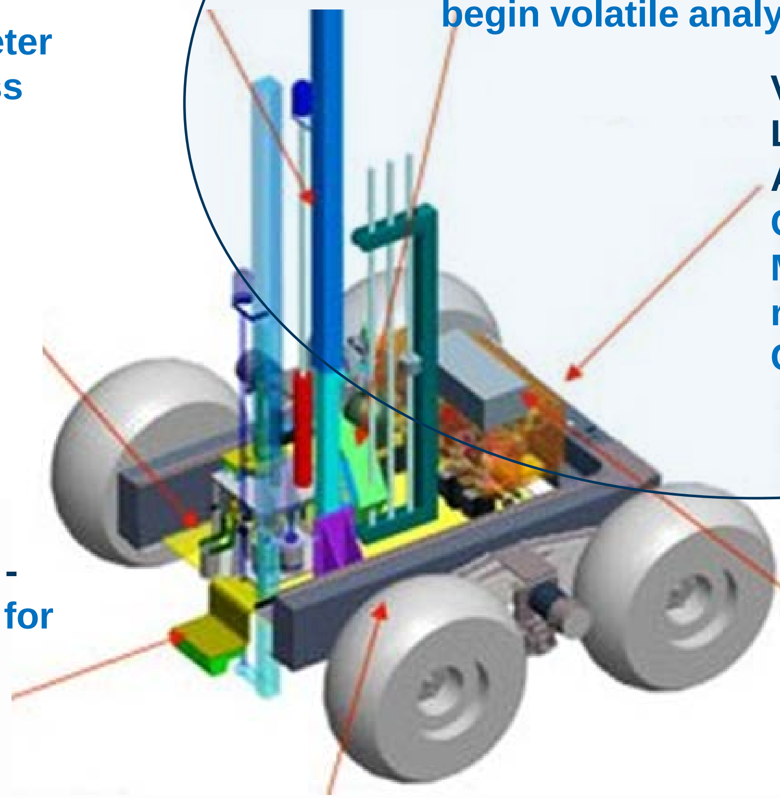
A simulation test of the RESOLVE payload was the first use the new Firing Room 4 in the Launch Control Center at KSC. These tests allow scientists to study flight operations and design. This is in line with NASA's "test as you fly" philosophy. *I was there!*

Rover with RESOLVE Payload and Subsystems

Volatile Content Extraction - Oxygen & Volatile Extraction Node (OVEN)
Temperature Range <100 °K to 900 °K to heat regolith and begin volatile analysis in GC

Subsurface Sample Collection - Core Drill
Complete core to 1 meter
Minimal/no volatile loss

Sample Evaluation Near Infrared Spectrometer -
Mineral characterization and ice/water detection
Illumination source



Volatile Content Evaluation - Lunar Advanced Volatile Analysis (LAVA)
Complete GC-MS analysis
Measures Water content of regolith
Characterizes volatiles

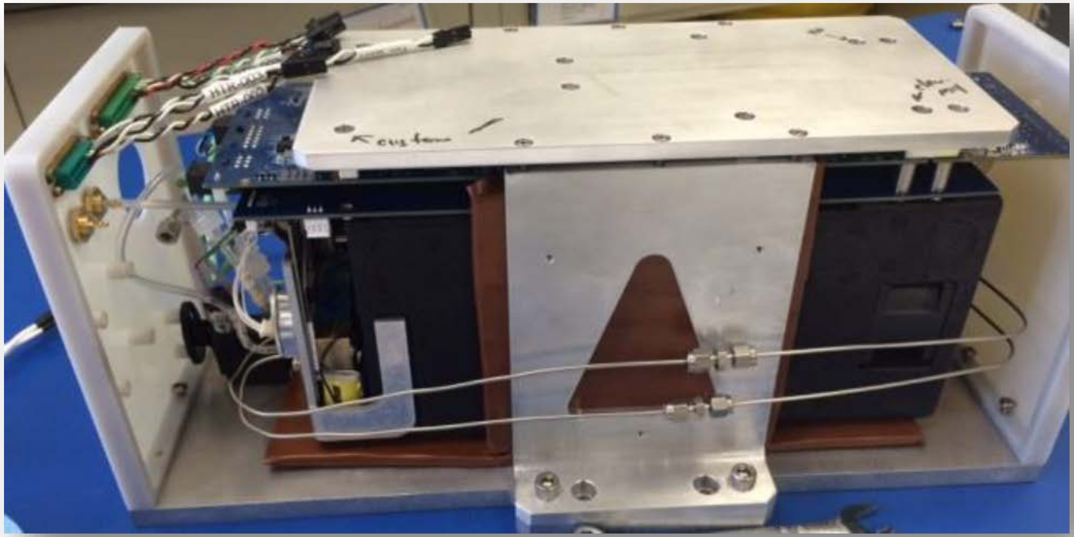
Resource Localization -
Neutron Spectrometer for detecting hydrogen

Surface Mobility/Operation -
Autonomous navigation using cameras and sensors

Lunar Advanced Volatile Analysis (LAVA) Testing

Overall Objectives

- **Identify and quantify water as well as other low molecular weight volatiles of interest for ISRU**
- **Analyze gas sample evolved from OVEN subsystem via gas chromatograph-mass spectrometer (GC-MS).**

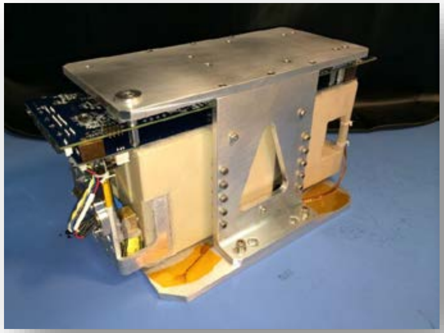


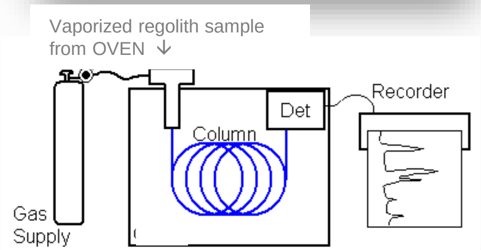
LAVA Physical Architecture

Lunar Advanced Volatile Analysis (LAVA) Testing

Gas Chromatography Testing Objectives

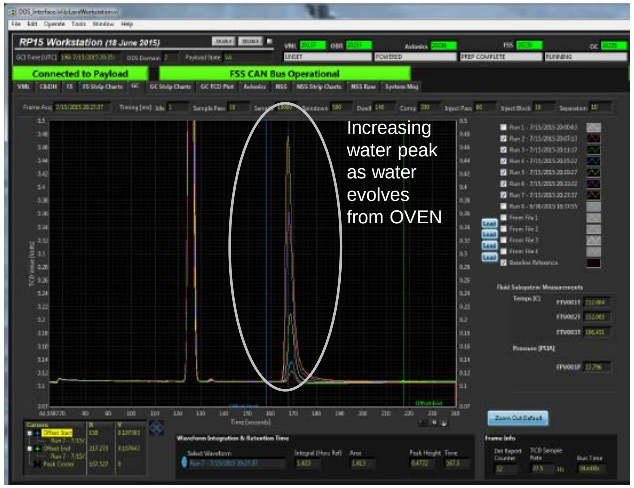
- **Enhance integration of the Resource Prospector '15 payload and rover**
- **Volatile analysis demonstration measuring increasing water concentration as regolith simulant temperature increases**
- **Verify detection of 2% and 5% water-doped regolith simulant**
- **How it works: Inside OVEN's crucible, a regolith sample is vaporized and mixed with a carrier gas. Mixture travels through GC column; separated into components. Detector identifies components; transmits signal to a chart recorder. Produces a Gaussian peak, with the area of the peak proportional to the number of molecules in signal. Water peak area is utilized with calibration curves to identify the concentration of water present in the regolith.**

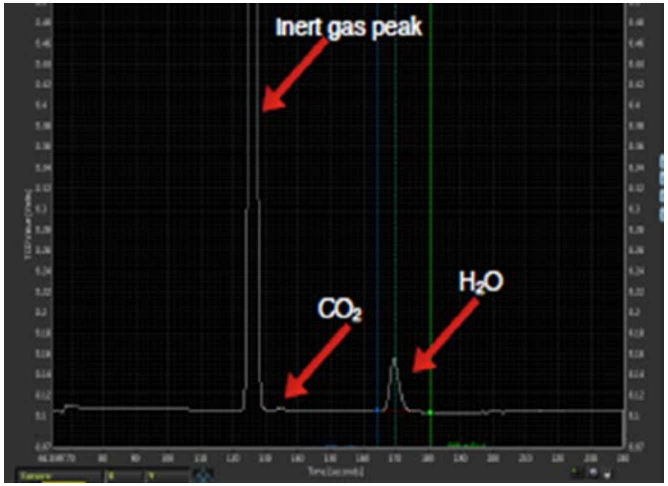




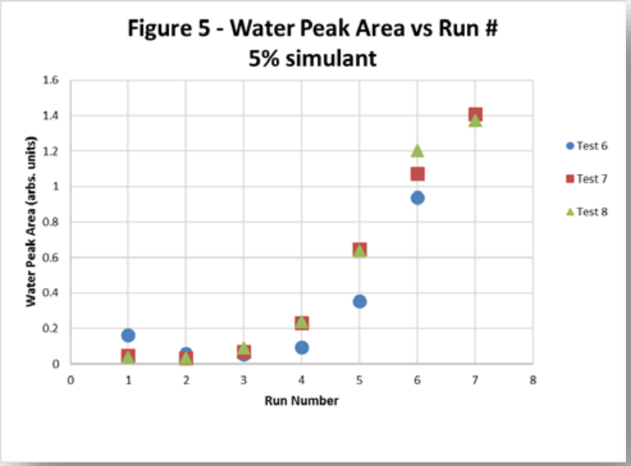
Gas Chromatography Testing

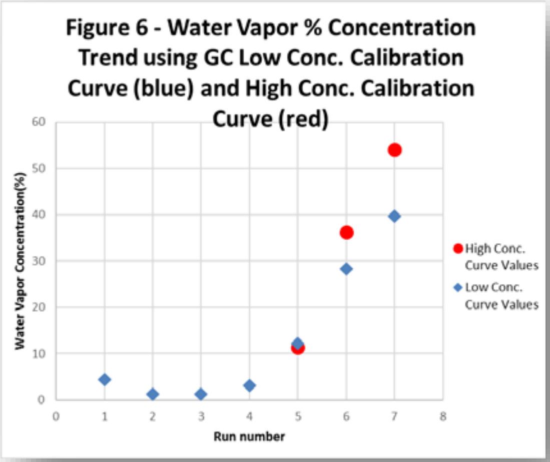
Results: GC successfully detects 2% and 5% water-doped samples





To quantify peak area, integration is used with the retention time, which is unique for each gas, as the limits. In Figure 4, peak area is identified for inert gases, CO2, and water . Water peak area from water-doped simulant tests (Example: Figure 5) is used to plug into calibration curves that will help identify the concentration of water present (Example: Figure 6).

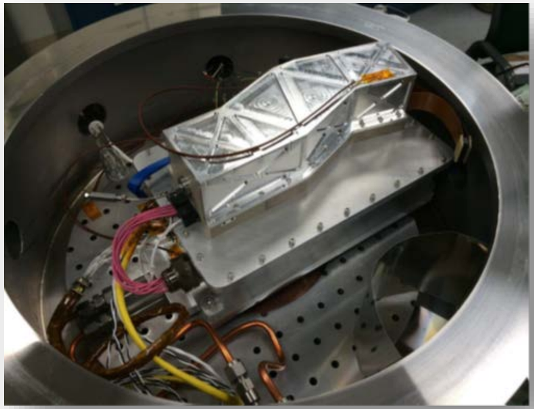


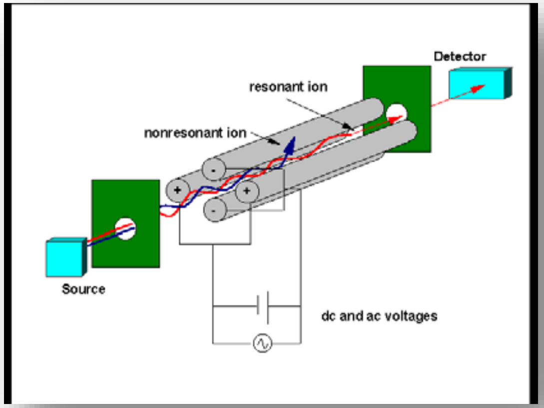


Lunar Advanced Volatile Analysis (LAVA) Testing

Mass Spectrometry Testing Objectives

- Verify ability of quadrupole mass spectrometer (QMS) to detect volatiles under simulated lunar conditions (cryogenics/vacuum)
- Understand behavior of electronics in vacuum
- How it works: QMS filters ions by mass-to-charge ratio (m/z) by alternating voltages in rods that run parallel to ion flight paths. Voltages affect the ion trajectory. Ions of a certain m/z pass through the filter, while other ions are deflected.





Mass spectrometer with electronics in vacuum chamber

Mass Spectrometry Testing

Results: tests verified reproducibility and accuracy of MS for detecting volatiles like nitrogen, oxygen, and carbon dioxide in lunar vacuum

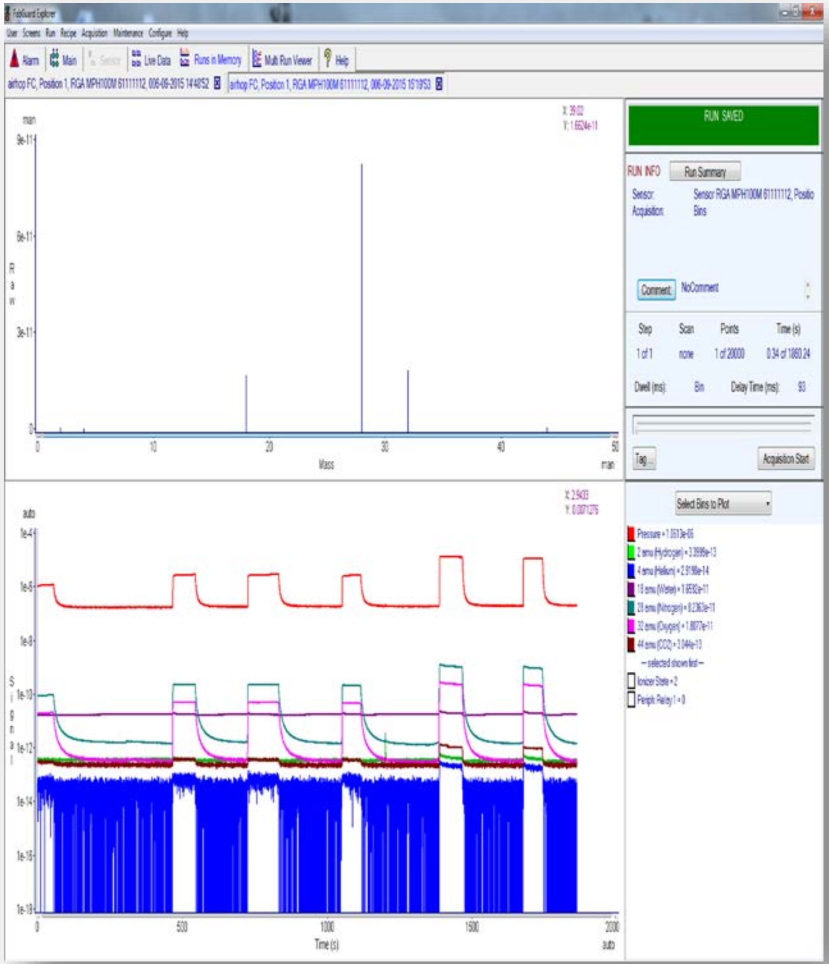
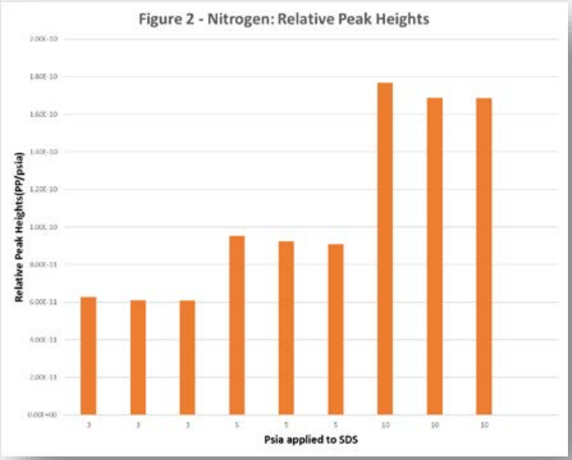
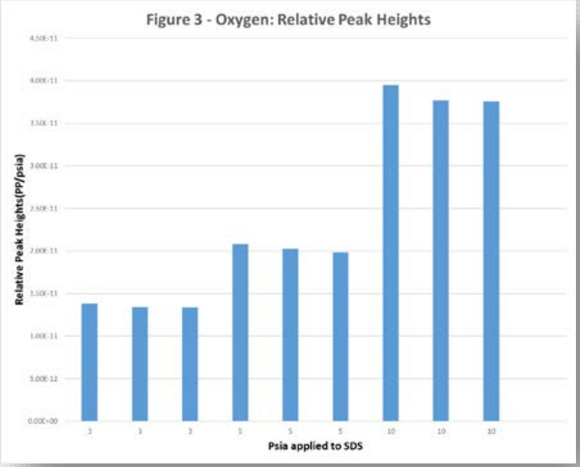


Figure 1. Gas Analysis software identifies the signal, or partial pressure, throughout the time interval of the test. The different colors represent pressure and the atomic mass units of elements or compounds.





Examples of Relative Peak Heights for volatiles. Pressures of 3, 5, and 10 psia applied to Sample Delivery System indicate the linear relationship between flow and pressure for nitrogen (Figure 2) and oxygen (Figure 3) and demonstrate that the results are reproducible.

Resource Prospector, RESOLVE and LAVA Mission Simulation

https://www.youtube.com/watch?v=fMXWsiaEK6Q&feature=youtu.be

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